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WHAT IS CLAIMED IS:

1. Apparatus for controlling the polarization of an incident beam of electromagnetic radiation comprising:

photonic crystal means, and

means for directing said incident beam of electromagnetic radiation at said photonic crystal means,

wherein said photonic crystal means comprises a crystalline lattice having cells with a defined periodic geometry that produces a polarization-dependent band structure by interference between Bragg reflections from many material interfaces for electromagnetic radiation.

2. The apparatus of claim 1 wherein said beam propagates in the plane of periodicity of a two-dimensional (2D) photonic crystal.

3. The apparatus of claim 1 wherein said beam propagates in any direction in a three-dimensional (3D) photonic crystal.

4. The apparatus of claim 1 wherein said beam is a polarized beam of EM radiation and wherein said photonic crystal means includes a transparent spectral region at a lower frequency than the fundamental band gap or between two band gaps, and that portion of said beam in said transparent spectral region is transmitted through the crystal and the polarization of said transmitted beam is altered by said photonic crystal means, whereby said

crystal functions as a waveplate.

5. The apparatus of claim 1 wherein that portion of said beam having said first wavelength is exponentially attenuated by said photonic crystal means and is reflected so that said apparatus functions as a reflection waveplate.

6. The apparatus of claim 1 wherein said incident beam of EM radiation includes first and second polarization components, and wherein said photonic crystal means reflects said first polarization component and transmits said second polarization component, thereby functioning as a polarizer.

7. The apparatus of claim 5 wherein said transmitted beam and said reflected beam can have any angle relative to said incident beam, whereby said apparatus is not limited by Brewster's angle.

8. An apparatus for maximizing conversion efficiency in nonlinear optical mixing processes between incoming, polarized optical beams and output, polarized optical beams comprising:

birefringent photonic crystal means composed of material with optical nonlinearity for achieving phase matching of said output beams with said incoming beams, wherein said birefringent photonic crystal means is adapted to reduce the wavevector mismatch Δk between said incoming and output beams to zero using said photonic crystal birefringence.

9. The apparatus of claim 8 wherein said photonic crystal means is adapted to achieve phase matching without the use of or minimal use of angle tuning or temperature tuning.

10. The apparatus of claim 8 wherein said polarized input beam has frequency ω_1 and first wavevector k_1, and said polarized output beam has frequency $m\omega_1$ and second wavevector k_2, wherein said photonic crystal is adapted to reduce the wavevector mismatch between said input and output beams to zero.

11. The apparatus of claim 8 wherein said photonic crystal means is composed of material that is not necessarily intrinsically birefringent.

12. The apparatus of claim 8 wherein said photonic crystal means is adapted to eliminate the walk-off of ordinary and extraordinary waves characteristic of phase matching with angle tuning.

13. An optical apparatus for selectively changing a first known polarization of an input beam to a second, predetermined polarization of an output beam, comprising:

a photonic crystal means, and

means for directing said input beam at said photonic crystal means,

wherein said photonic crystal means comprises a crystalline lattice having cells with a defined periodic geometry that produces a band structure by interference between Bragg reflections from many material interfaces for electromagnetic waves.

14. A method of converting the polarization of an incoming beam of light from a first, known polarization to a second, selected polarization, comprising the steps:

directing said incoming beam of light along a predetermined path,

causing said incoming beam to enter a photonic crystal wherein said photonic crystal is adapted to convert said first polarization to said second polarization, and

causing a beam of said second selected polarization to either be transmitted through or reflected off of said photonic crystal.

15. An optical apparatus for creating a delay line arising from a transfer of energy between two different polarizations of electromagnetic (EM) waves, comprising:

birefringent crystal means,

polarizer means in series with said birefringent crystal means, and

means for directing said EM wave through said birefringent crystal means and said polarizer means,

wherein either a delayed or advanced transmitted electromagnetic waveform or wavepacket results by adjusting either the relative angular orientations of said birefringent crystal means, said polarizer means, and/or said incident EM wave polarization.